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TASK OBJECTIVES

During the first half of 1997, we continued to work on algorithm code testing and deliveries. We also were involved in field-based, AVIRIS, AVHRR, and Landsat TM-based, validation actvities. Specific objectives and tasks included:

*   complete version 2 code for the vegetation index products;
*   level 3 algorithm testing and BRDF integration into the level 3 compositing algorithms;
*   exercise algorithms with the daily, 1km AVHRR data stream.
*   NDVI continuity analysis with AVIRIS data;
*   NDVI saturation analysis and the use of the green channel over forested areas;

WORK ACCOMPLISHED

1.   Level 3 Vegetation Index Compositing Algorithm

Some adjustments were made to the level 3 vegetation index compositing algorithms, based on changes in the level 2 surface reflectance product and insights provided by working with Pathfinder AVHRR data. Since reflectance data will not be produced for pixels with cloudy QA flags, the composite algorithm will not include a straight forward MVC approach (classical approach; maximum value of the VI for a set time interval). However since the cloud mask might not be operational directly after launch, several switches are being built in to allow for the processing of less ideal data (e.g. if the cloud mask is not available, the constraint view angle MVC approach will be applied; the view angle constraint can also be relaxed as needed). The code was redesigned to allow for changes in the different modules to facilitate easier code maintenance, debugging and algorithm updates.

The BRDF-based normalization algorithm was optimized and has been shown to improve the compositing performance significantly (10-40%). The algorithms for the five vegetation index products have been frozen although slight changes can still be implemented. The five products differ with respect to the computed vegetation index, composite algorithms and spatial and temporal resolutions: a) NDVI at 250 m and 16 day resolutions; b) NDVI and EVI at 1km and 16 day resolutions; c) NDVI and EVI at 1km and monthly resolutions; d) NDVI and EVI at climate modeling grid (CMG - 25km) and 16 day resolutions; e) NDVI and EVI at CMG and monthly resolutions. The output products will also contain the reflectance data used to compute the VI, QC and geometric data (view and sun angles).

Much progress was made in meeting V2 coding and file specification requirements. The quality control flags and metadata fields were updated to improve QA analysis. Strides are being made to include everything in the V2 code delivery in August, 1997. The HDF integration and PGS toolkit are also being integrated in the V2 delivery. Requirements for the Version 2 synthetic data sets were submitted to SDST in January. The HDF file specifications of (MOD13) the vegetation index product (MODIS Version 2 software) and the PSAs (product specific attributes) were submitted to SDST in March and April of 1997 respectively. Prior to Aug 1 our SCF delivers the first version of V2 of the MODIS L3, 16 day 250 m VI product.

A years worth of AVHRR Pathfinder I data were reprocessed to determine the differences between several composite scenarios and different vegetation indices (NDVI, SR, DVI, SAVI). The composite scenarios included the new MODIS and 'old' maximum value composite (MVC) scenarios.   The MODIS vegetation index compositing software and algorithms were also adjusted to test and evaluate the AVHRR PATHFINDER II data sets (complete atmospheric correction) to aid in the MODIS vegetation index compositing research. This evaluation is in progress.   Arrangements were also made with the EROS Data Center (EDC) in June to ingest daily 1 km AVHRR data sets of the western hemisphere to work on vegetation index algorithm development and evaluate the MODIS algorithm with respect to possible artifacts.

2.   Landsat TM Saturation Analysis

A vegetation signal 'saturation' analysis was made and completed over a set of global forest cover types. There is some concern that the MODIS 'red' band, being very narrow and centered on the peak chlorophyll aborption, would cause vegetation indices to become overly sensitive to vegetation reaching an asymptotic value at lower vegetation densities than encountered, thus increasing the saturation problem over dense, forested areas. Suggestions to this problem have included using the 'green' band, the middle-infrared band, or a broader, red+green, band. We found that these options did little to alleviate the problem with the NDVI, however, use of alternative indices indicated no saturation problem in the first place. The results of this study will be presented at the IGARSS' 97 Symposium. The title and abstract are written below:

Title: The Use of Vegetation Indices in Forested Regions: Issues of Linearity and Saturation, by Alfredo R. Huete, HuiQing Liu, Wim J.D. van Leeuwen.

Abstract: Numerous problems and difficulties have been reported with the use of vegetation indices in high biomass, forested regions. In this study we analyzed Landsat-5 Thematic Mapper (TM) scenes from various temperate and tropical forested biomes, representing needleleaf and broadleaf canopy structures in the Pacific Northwest (Oregon), Eastern U.S. (Harvard Forest), southern Chile and , the Amazon region near Manaus, Brazil. The TM scenes were partially (Rayleigh-ozone) and totally atmospherically corrected and reduced to MODIS surface reflectance data at 250 m and 500 m pixel sizes. Various types of vegetation indices (VIs) were then computed including ratio-based indices such as the normalized difference vegetation index (NDVI), orthogonal-based indices such as the green vegetation index (GVI), and alternative atmospheric and/ or soil correcting indices. The NDVI was also tested utilizing the green and middle-infrared (MIR) bands. The NDVI was found to be fairly saturated across all of the tested forested biomes. Replacement of the 'red' band with 'green' and 'middle-infrared' bands did not reduce the saturation problem. In contrast, the remaining indices remained sensitive to canopy structure variations over all of the forested biomes with minimal saturation problems. The high 'penetrating' capability of the near-infrared band through forested canopies was the dominant factor in vegetation index sensitivity and performance. We found that indices with higher weighing coefficients in the "near-infrared" to be the best approach in

extending vegetation index performance over forested and dense vegetated canopies.

3. AVIRIS Data 'Continuity" Analysis

      Relatively 'clear' AVIRIS images were selected from the SCAR-B experiment in Brazil for sensor band and bandwidth analysis of reflectances and vegetation indices among different sensors. The goal was to develop translation parameters (equations) among the different considered sensors (MODIS, TM, AVHRR, and GLI). Four sites were chosen (north Brasilia, Campo Grande, Porto Velho, and Cuiaba) for derivation of surface reflectances. The ATREM and '6S' codes were utilized in atmosphere correction. The resulting images were then convoluted into specific sensor bandwidths and vegetation indices computed.

      Correlations between NIR, red, NDVI, SAVI, and SARVI were computed to generate the linear equations to be used in the translation from one sensor to the other. Overall results show a strong linearity between the sensors, nonetheless, sensitivity to the bandpass and atmospheric correction were obvious. The results of this research were presented in a poster at the AGU spring meeting in Baltimore/MD. The title and summary are written below:

Title: Translation and Continuity of Spectral Vegetation Indices Derived from MODIS, AVHRR and LANDSAT Bands Using AVIRIS Data from SCAR-B

      The Advanced Very High Resolution Radiometer (AVHRR) and LANDSAT Thematic Mapper data have been used extensively for global monitoring of vegetation dynamics such as seasonal growth and land cover change. The Moderate Resolution Imaging Spectroradiometer (MODIS) will be used to continue this effort of data collection, but with different spectral characteristics that are expected to enhance vegetation monitoring capabilities. Along with the use of advanced sensor systems, there is a need to develop mechanisms for data translation, continuity, and integrity. The objective of this research was to analyze the effects of differences in sensor bandwidths on the interpretation of vegetation indices, taking into account the spectral properties of vegetation, soils, and atmosphere. A second objective was to determine the feasibility in developing

translation coefficients for the vegetation indices obtained from the various sensors.

For this analysis, AVIRIS data that was acquired during the Smoke, Cloud and Radiation experiment in Brazil (SCAR-B) in 1995, was used for vegetation index-sensor bandwidth evaluations. Vegetation cover types included savanna, primary forest, secondary forest, and pasture sites. The high spectral and spatial resolution (10nm and 20 m respectively) AVIRIS data were processed to apparent reflectances (no atmospheric correction), Rayleigh corrected reflectances, and atmospherically corrected surface reflectances, after which the data were convoluted to MODIS, AVHRR and LANDSAT spectral bands. The normalized difference vegetation index (NDVI), soil adjusted vegetation index (SAVI), and the soil and atmosphere resistant vegetation index (SARVI) were computed for all sensor bandwidths.

Translation coefficients between MODIS and AVHRR and LANDSAT were computed for a range of vegetation and atmospheric conditions. The MODIS and TM bands were shown to have reduced many of the atmospheric problems present with the AVHRR bands. Nonetheless, all vegetation indices were strongly influenced by atmospheric effects, such as smoke aerosols, water absorption and Rayleigh scattering. Linear regression analysis showed the MODIS-NDVI, AVHRR-NDVI, and LANDSAT-NDVI data sets to be highly linear. The results of this analysis show a strong correlation of NDVI, NIR, and red between MODIS, AVHRR, and LANDSAT. These linear equations can easily be used to translate between the two sensors.

Some deviations were obvious and were attributed to the differences in the target spectral characteristics (e.g. vegetation and soils), differences associated with sensor band width, and the atmosphere absorption windows for water vapor. When comparing atmospherically corrected MODIS-NDVI with present day, Rayleigh corrected AVHRR-NDVI we see very large differences in the resulting NDVI values with MODIS-NDVI values much higher than AVHRR-NDVI. In forested areas, VI saturation problems were also found to be greater with the NDVI computed from LANDSAT and MODIS bands in comparison to the NDVI computed from the AVHRR. Atmospheric correction improved the NDVI signal, but also worsened the saturation problem. In contrast, SAVI had similar bandpass translation behavior but had less saturation problems. The SARVI was less

sensitive to atmospheric effects but the coefficients of the SARVI equation were bandpass sensitive.

4. Aerosol and Smoke Analysis at Scar-B

    We are investigating the relative merit of utilizing the 'atmospheric resistance' concept within the design of the vegetation index equation, primarily through use of the blue band. This analysis is being conducted, recognizing the limitations of the coarser resolution, 'land' aerosol product, which assumes uniformity within a grid cell. A test of how the spatial variability of aerosols could affect the vegetation index was made using the 'blue' band as well as the 'middle-IR' band which penetrates smoke. This study was made over the SCAR-B experiment under light and heavy smoke (biomass burning) conditions. The results were presented at the AGU Spring meeting in May.

 Title: Vegetation Detection through Smoke-filled AVIRIS Images at SCAR-B: An Assessment Using MODIS Bandpasses, by Tomoaki Miura, Alfredo R. Huete, Wim J. D. van Leeuwen, Kamel Didan

    Vegetation detection through smoke is complicated by the spatial variability of aerosols and the high sensitivity of the chlorophyll bandpasses to smoke. Various suggestions have been made to correct for aerosols on a pixel by pixel basis. These include the use of the blue band for correction of the red band, known as the atmospheric resistance concept. Another approach is to use the middle-infrared (MIR) band for the red band since the longer wavebands are relatively insensitive to smoke yet remain sensitive to differences in vegetation. In this study, we analyzed and compared the atmospheric resistance vegetation indices and the MIR-derived vegetation indices (VI) with respect to their utility in vegetation analysis through variable smoke contamination.

    Three AVIRIS images were acquired during the Smoke, Cloud and Radiation experiment in Brazil (SCAR-B) in August - September 1995. The images included primary and secondary tropical forest vegetation as well as burned fields and pastures and were acquired under variable aerosol and smoke conditions resulting from active burning of forest lands. These AVIRIS images were convolved to the Moderate Resolution Imaging

Spectroradiometer (MODIS) bandpasses and corrected for Rayleigh scattering with 6S. Levels of smoke contamination were classified as thick, thin, and clear. Different vegetation classes were identified under all three smoke conditions. The blue and red bands were most sensitive to smoke while the MIR bands were insensitive to the smoke. The NIR band remained sensitive to smoke but to a lesser extent than the shorter wavebands. As a result, the atmospheric resistant vegetation indices, which incorporated the blue band, improved vegetation detection relative to the non-resistant VIs, but were still significantly affected by smoke conditions. The MIR-based VIs were able to minimize variable smoke noise to a greater extent than the blue band VIs, but were still somewhat sensitive to different optical thickness of smoke. These effects can be attributed to the sensitivity of the NIR band which in all cases remain uncorrected.

5. Validation Activities and Early Results

5.1 La Jornada and Walker Branch mini-campaigns

Activities over the last six months include design and implementation of two prototype validation experiments. One of those was in La Jornada, LTER site, near Las Cruces, New Mexico and the other was in Walker Branch Watershed in Oak Ridge, Tennessee. La Jornada is a semi-arid rangeland, consisting mainly of short grass and brush, situated in a valley between two mountain ranges. Walker Branch is an eastern deciduous forest, mainly oak-hickory, maple and pine with a landscape of gently rolling hills. These two sites were selected to provide two extremes in vegetation types (almost no vegetation to dense forest) for prototyping a robust and readily deployable strategy for global MODIS Land products validation.

Aircraft-mounted radiometers were used to collect bidirectional reflectance data from three 1 km by 1 km plots. Two radiometers were used for this purpose, one was always looking nadir, with the other (adjustable) looking at 15 degree, 30 degree and 45 degrees off nadir angles during the over-flights. Flight lines were set at both principal and orthogonal planes and both forward and backscatter data were collected. The field of view (fov) for both radiometers was 1 degree, however, radiometric data were collected at both 1 degree and 15 degrees to test the effects of low altitude view angles (100 m AGL) on bidirectional

reflectances of vegetation. Flights were also made at two solar zenith angles to assess sun angle effects on the VI compositing routine. Ground radiometric data, fAPAR and LAI data were also collected from the same plots. Similar data collection will be done in Walker Branch during the first week of August.

Preliminary analyses of La Jornada data show that the1 degree fov yielded higher NIR reflectances. This needs to be investigated. Also, different bidirectional reflectance distribution models are being run with the data to characterize the BRDF of semi-arid vegetation. Different VIs calculated using the reflectance data are being correlated to the LAI and fAPAR data. Another similar set of data will be collected in early September (green season) of this year from La Jornada to compare the effects of seasonal variation. The results of La Jornada and Walker Branch field campaigns will be presented at a remote sensing conference to be held in Alexandria, Egypt later this year.

5.2   Data from other field campaigns:

For last two decades, VIs have been used to derive vegetation biophysical parameters such as LAI, fPAR and NPP. The objectives of the MODIS VIs are to:

a) discriminate spatial and temporal variations in vegetation
b) show phenological profiles of global vegetation
c) allow for coupling with biophysical parameters (LAI fPAR) of global vegetation.

Validation of VI products means finding out if the VIs are able to perform properly in the light of above mentioned objectives. With these criteria in mind, an important step in VI-biophysical validation is is to utlize data sets from different past experiments conducted over varying types of vegetation from around the globe. Currently, radiometric and biophysical data from grassland sites (FIFE, 1987) and aspen and spruce sites (Superior National Forest, 1984) have been analyzed. The vegetation indices NDVI, SAVI, SR and NIR-red were calculated for the three above mentioned vegetation types. Of the 3 vegetation types analyzed, only Aspen showed a positive relation between LAI and VIs. In the case of the NDVI, Aspen tended to saturate at LAI = 2.   None of the VIs showed any positive response with LAI (from 0.5 to 3.5) in case of Spruce.   This study

is far from complete and the data set are still too sparse at this time to draw a conclusion about global trends of VI-LAI behavior.

6.   MODLAND - GLI Summary Report

Summary report of GLI Science Team Meeting, June 11-14 in Kinugawa, Japan. (Alfredo Huete)

The main issues that concern MODLAND (as co-Investigators) include:

*   GLI would like an atmospheric correction algorithm over the land. However, this will not be as easy as with MODIS in that there will not be an aerosol product derived over land; the BRDF capabilities of GLI, and hence coupling to atmospheric correction, will be very limited and there is no BRDF product for GLI.   POLDER will fly on the same platform, but with an ~8km resolution, its utility for GLI atmosphere correction is questionable.   Currently, the funded post-doc for this, Dana Kerola, is adapting the AVHRR-Pathfinder 1 code (Rayleigh and ozone correction) to the GLI. Any additional corrections for water vapor or aerosols will be based on his work and in collaboration with Eric Vermote.

*   Steve Ackerman will produce an 8-bit cloud mask.

*   The GLI land team leader, Yoshio Awaya, has asked if he can utilize Steve Running's NPP algorithm as a starting point or at-launch code for the GLI - NPP product. Yoshio feels his NPP algorithm will not be ready by the January 1999 launch date.

*   Other algorithms / codes in which GLI is interested in collaborating with MODIS include Vegetation Indices, Vegetation Change, and LAI. Land surface temperature is being produced by Fred Pratt (CSIRO), and land cover is being handled by several people and is primarily restricted to Asia. Michelle Verstraete will produce an fAPAR product.

*   As noted in the attached summary below, there is uncertainty in the tilt mode operation of the GLI sensor. The oceans group would like the sensor to be always tilted (±20°) when it views any water; while the land group would like nadir views whenever there is land. The atmospheres and

cryosphere groups are neutral but desire consistency. This is reminiscent of MODIS-T.

*   Validation: GLI is interested in the MODLAND validation sites. Most sites are PI based and include;
        -        Mongolia grasslands (short to tall grass)
        -        Mekong Delta, Vietnam
        -        Northeast China, CERN forest site
        -        Tomakomai and Mt. Fuji, Japan (spruce, larch, and beech)
        -         3 sites in Australia (New South Wales - short-grassland; Allo Springs - semi arid; N. Australia - tropical).
        -        Hokkaido Island, Japan (wetlands)
        -        GLI will look into becoming involved with CEOS and associated CAL/VAL sites.

*   AMSS (46-channel airborne simulator) data should become available to us)

*   Dr. Honda has a web site for entry of GPS photos over global validation sites (http://gin.cr.chiba.u.ac.jp). Dr. Honda also has an operational remote control helicopter with 11kg payload, succesfully tested over Mongolia test site.

*   Craig Trotter (New Zealand) spoke on topographic corrections. He reported that incidence and exitance effects are independent. Incidence effects dominate variations in radiance while exitance effects are more wavelength dependent.

7. SCF Report

        The Terrestrial Biophysics and Remote Sensing lab (TBRS) SCF is in the process of transition to a thoroughly integrated operation that will be able to provide the high level of computing services necessary to meet the increasing resource and functionality demands placed on it by the EOS MODIS project. A professional systems analyst has been hired to take responsibility for the design and implementation of an SCF strategic development plan that will meet the project goals.

The TBRS SCF is structured as a three tier computing environment: 1) Server systems at the core, 2) Workstations that are closely integrated with the servers as an extension of the core, and 3) Personal computers that are loosely integrated with the core environment. Each tier takes on a portion of the SCF computing load in a form that is focused on its particular capabilities. The TBRS SCF has been operating on a building wide ethernet subdomain that is configured as a single, arbitrated bus. The packet collisions that have resulted from the increasing contention for the bus by new systems installed in the building, especially the TBRS server, has created a need for a better solution. A two level TBRS network has been designed based on ethernet switching hardware, which is currently being acquired. The switched ethernet will create a non contention domain for the TBRS SCF so that the full bandwidth of the network will always be available for systems in the facility.

Inter-facility network data transfers, however, have become an increasing bottleneck. Currently, for example, the SCF facility has systems located in two buildings (see Facility Move below) so that instead of a single network hop, three are involved in reaching systems across buildings, thus introducing significant network latencies. Even after the SCF systems have been consolidated into one building, interaction with colleagues will become increasingly sluggish as the existing University infrastructure struggles to keep up with demand. The TBRS staff continue to collaborate with other members of the University community, especially staff from the Center for Computing and Information Technology (CCIT), to seek cost-effective solutions with broad benefits. For example, the TBRS systems analyst has been appointed as a net manager to the College of Agriculture and designated as a Departmental representative to the University Information Technology Council.

The inter-facility data transfer issue of more direct concern to the TBRS SCF, however, is how the large amounts of data that need to be processed here will be delivered from the EOS production and archive facility. If data is delivered on tape, there will a lot of tapes and a lot of manual work (at the data center as well as the SCF). The network is the preferred media, since manual work can be minimized and automated data routing maximized. But there is significant concern about the ability of the existing WAN connections to reliably transfer the needed data volumes in a timely manner. There have been speculations, with no substantiation,

that the TBRS SCF will receive a connection to the new high speed "gigabit" network when it arrives at the University of Arizona. However, information to use for planning implementation schedules, infrastructure requirements, interface and protocol issues, and cost budgeting have not been available. This is a significant unresolved issue that needs to be addressed.

8.   Anticipated future action

    The tasks for the coming half year will include further development of the vegetation index compositing algorithms and related science issues. Research will focus on:

*   the use of a historical BRDF data base in combination of vegetation index composite scenario; to be tested on 8 km AVHRR (test alternative compositing algorithms).

*   sun and view angle correction with BRDF models at climate modeling grid (CMG) level.

*   1 km AVHRR compositing (June 1995- end 1995) (code development for orbit stitching and for cloud mask/land mask as well as integration with current composite schemes). This will help to prototype 1 km VI on a continental scale.

*   set up QA analysis and develop tools for analysis of MODIS data prototype the CMG data sets and products - testing V2 code (September- December).

*   Fine tuning algorithm for version 2.1.

9. Papers Presented

    Several papers were written and presented at conference proceedings and workshops. The abstracts from the AGU and IGARSS meetings were presented above.

Alfredo Huete and Wim van Leeuwen attended the "Workshop on Multi Angular Remote Sensing Progress and Advancing BRDF Usefulness in the EOS era and Beyond", January 29-31 at the University of Maryland Conference Center.

Alfredo Huete gave a presentation entitled "Vegetation indices and their limitations for biophysical parameter retrieval" (Invited).

Wim van Leeuwen presented a poster at the BRDF workshop entitled: "Exploiting BRDF for global compositing of vegetation indices".

Two posters were presented at the 7th International Symposium on Physical Measurements and Signatures in Remote Sensing, Courchevel, France, April, 7-11,1997:

1. "Bioclimatic and vegetation index based derivation of biophysicalparameters: a Chilean example" Huete,A., Santibañez,F., de Lira,G., van Leeuwen, W.., Morales,L., De la Fuente,A., Uribe,J.

2. "Modeling bi-directional reflectance factors for different land cover types and surface components to standardize vegetation indices", van Leeuwen, W.J.D., Huete, A.R., Didan, K., and Laing, T.

Currently preparing two poster presentations for the IEEE-IGARSS'97 Symposium in Singapore, August:

"Quality assurance of global vegetation index compositing algorithms using AVHRR data" by Wim J.D. van Leeuwen*, Trevor W. Laing, Alfredo R. Huete.

"The use of vegetation indices in forested regions: issues of linearity and saturation" by Alfredo R. Huete, Wim J.D. van Leeuwen and Huiqing Liu.

10. Publications

Leeuwen van, W.J.D., A.R. Huete, C.L. Walthall, S.D. Prince, A. Begue and J.L. Roujean, 1997. Deconvolution of remotely sensed spectral mixtures for retrieval of LAI, fAPAR and soil brightness. J. Hydrology. HAPEX-Sahel special issue 188-189(1-4), pp 697-724.

Huete, A.R., Liu, H.Q., Batchily, K., and van Leeuwen, W., 1997, A comparison of vegetation indices over a global set of TM images, Remote Sens. Environ. 59:440-451.

van Leeuwen, W.J.D. Trevor W. Laing, and Alfredo R. Huete, 1997. Quality Assurance of Global Vegetation Index Compositing Algorithms Using AVHRR Data. IEEE- IGARSS'97, Singapore (pp 1-3; in press)

Huete, A.R., H. Liu, W.J.D. van Leeuwen, 1997. The Use of Vegetation Indices in Forested Regions: Issues of Linearity and Saturation. IEEE-IGARSS'97, Singapore (pp 1-3; in press)

W.J.D. van Leeuwen, A.R. Huete., K. Didan and T. Laing, 1997. Modeling bi directional reflectance factors for different land cover types and surface components to standardize vegetation indices. 7th Int. Symp. Phys. Measurements and Signatures in Remote Sensing, Courcheval. (pp 1-8; in press)